Research Note 83-45

Nonlaboratory Techniques for the Study of Cognitive and Decision-Making Processes: A Description and Selected Bibliography

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Research Institute for the Behavioral and Social Sciences

December 1983

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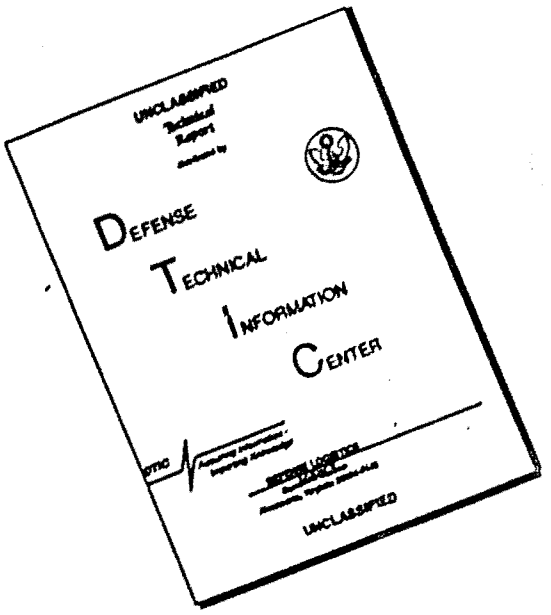

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: Research Note 83-45	2. GOVT ACCESSION NO.: AD A141732
3. RECIPIENT'S CATALOG NUMBER:	
4. TITLE (and Subtitle): NONLABORATORY TECHNIQUES FOR THE STUDY OF COGNITIVE AND DECISION-MAKING PROCESSES: A DESCRIPTION AND SELECTED BIBLIOGRAPHY	5. TYPE OF REPORT & PERIOD COVERED: Technical Report
	6. PERFORMING ORG. REPORT NUMBER: --
7. AUTHOR(s): Jo Hall, Ruth H. Phelps	8. CONTRACT OR GRANT NUMBER(s): --
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Army Research Institute for the Behavioral and Social Sciences (PERI-SF), 5001 Eisenhower Avenue, Alexandria, VA 22333	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 2Q263739A793
11. CONTROLLING OFFICE NAME AND ADDRESS: U.S. Army Research Institute for the Behavioral and Social Sciences (PERI-SF), 5001 Eisenhower Avenue, Alexandria, VA 22333	12. REPORT DATE: December 1983 13. NUMBER OF PAGES: 32
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): --	15. SECURITY CLASS. (of this report): UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE: --

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

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18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Research methodology	Information acquisition analysis
Decision-making processes	Critical incident technique
Cognitive processes	Delphi method
Nonlaboratory methods	Operations research
Verbal protocol analysis	Field research methods

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This technical report describes nonlaboratory research methods that can be adapted to examine covert cognitive and decision-making processes underlying the performance of a task. These techniques generally can be applied in the natural task setting with a minimum of interference and disruption of task performance. Summarized are nine methods classified under three main categories: process-tracing methods, applied research methods, and field research methods. In addition to a full description of each method, major references and selected annotations are included. While most of (Continued)

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these methods traditionally have not been used to study cognition, suggestions for their adaptation to cognitive applications are provided.

FOREWORD

With the use of increasingly sophisticated automated systems on both the current and future battlefields, the need for efficient, highly accurate, user-friendly soldier-machine interfaces becomes critical. Research on understanding the requirements and abilities of both the operator/soldier and the system needs to focus on maximizing the match between the soldier and the machine. General research areas designed to address this problem include the study of human abilities, computer capabilities, environmental influences, and specific task requirements.

One area of special interest is the exploration of research methods which can be used in the support and enhancement of the decision-making process within command, control, and intelligence centers. This technical report provides a description of and selected references for nine research methods that can be used to examine cognitive and decision-making processes. In general, these methods can be applied in the natural task setting with a minimum of interference with task performance. The methods are classified under three categories: process-tracing methods, applied research methods, and field research methods. While most have not been used previously to study cognition, their imaginative adaptation to this problem is indicated. Some preliminary suggestions are presented to help other researchers begin to use cognitive procedures to understand operational decision making.

NONLABORATORY TECHNIQUES FOR THE STUDY OF COGNITIVE AND DECISION-MAKING PROCESSES: A DESCRIPTION AND SELECTED BIBLIOGRAPHY

EXECUTIVE SUMMARY

Requirement:

To summarize research methods that can be used to identify the cognitive factors that impact on task performance when traditional laboratory techniques would disrupt or modify performance.

Approach:

Literature from several disciplines was searched and reviewed for nonlaboratory methods of potential value in the investigation of cognitive and decision-making processes. Methods of interest were selected and individually analyzed for adaptability to the study of cognition.

Product:

This report summarizes nine methods classified under three main categories: process tracing, applied research, and field research. Each method is described in terms of definition, history, procedure, benefits, and limitations, as well as general applications. A list of major references is made for adapting and utilizing each method in the study of cognitive and decision-making factors.

Utilization:

Using traditional experimental techniques to test perceptual, memory, information processing, and decision-making abilities is unsatisfactory since these processes are likely to change or interact during task performance under laboratory conditions. The methods summarized in this report generally can be applied in the natural task setting with minimal obstruction or disruption of task performance. While most of these methods have not been used to study cognitive processes, all of them show some potential for this use.

NONLABORATORY TECHNIQUES FOR THE STUDY OF COGNITIVE AND DECISION-MAKING PROCESSES: A DESCRIPTION AND SELECTED BIBLIOGRAPHY

CONTENTS

LIST OF TABLES

NONLABORATORY TECHNIQUES FOR THE STUDY OF COGNITIVE AND DECISION-MAKING PROCESSES: A DESCRIPTION AND SELECTED BIBLIOGRAPHY

INTRODUCTION

The purpose of this report is to summarize research methods that have potential for revealing the cognitive and decision-making processes underlying task performance when traditional laboratory techniques cannot be used. The emphasis is on methods that can be applied in the natural task setting with a minimum of interference with and disruption of the task performance. It is assumed that a definition already exists of the task and the environmental variables obtained by a task, job, or systems analysis. Yet to be defined are the cognitive (thinking, perception, memory) and decision-making variables necessary for task performance.

This search of methods resulted from frustration with identifying the cognitive factors that affect task performance using more conventional measures of cognitive processing such as choice, problem-solving efficiency, reaction time, and recall and recognition performance. Testing the perceptual, memory, information-processing, and decision-making abilities in laboratory experiments is unsatisfactory because these processes may well change, interact, or otherwise metamorphose during task performance in the field (Ebbesen & Konecni, 1975, p. 26).

While most of the methods summarized in this report have not been designed or used to study the covert cognitive processes underlying task performance, all show promise of yielding at least some insights. Clearly, an innovative cognitive or decision-making psychologist will have to adapt and implement these procedures.

This report is organized into four major sections: (1) Overview of Methods, (2) Process-Tracing Methods, (3) Applied Methods, and (4) Field Research Methods. The Overview section summarizes all methods and their similarities and differences on eight major variables. The three following sections contain descriptions of each method based on definition of method, history, procedure, benefits and limitations, general applications, and suggested cognitive applications. In addition, a list of major references and selected annotations is included for each method.

OVERVIEW OF METHODS

Eight major characteristics of each method are summarized in Table 1. Since the emphasis is on data collection in the field, most of the characteristics were chosen to compare the bias introduced by each method through alteration of the natural task context or intervention in task performance. The methods are organized into three categories: process tracing, applied research, and field research. The following is a description and explanation of each of the eight characteristics:

1. Source of the Data--who or what supplies the data of research interest.

Table 1

Summary of Methods Compared on Eight Major Characteristics

Method	Characteristics: Source of the data	Nature of the data	Scale of measurement of the data	Relative technical expertise required by the method[a]
PROCESS TRACING				
1. Verbal protocols	Subject	Verbatim verbal response	Nominal	2
2. Information acquisition	Subject	Objective record of behavioral responses	Interval Ratio	2
APPLIED				
1. Critical incident	Subject, observers, coworkers, etc.	Subjects' written narratives	Nominal	1
2. Delphi	Subject	Subjects' opinions	Nominal	2
3. Operations research	Model of the system	Values of the model that optimize performance	Ratio	3
FIELD RESEARCH				
1. Interview	Researcher	Subjects' verbal responses to questions, recorded by the researcher	Nominal	1
2. Questionnaire	Subject	Subjects' written responses to questions	Nominal Ordinal Interval	1
3. Observation	Researcher	Verbal or behavioral responses recorded by the researcher	Nominal Ordinal Interval Ratio	1
4. Unobtrusive measures				
a. Physical traces	Physical Material	Measures, weights, counts, etc.	Interval Ratio	1
b. Archives	Public & private records	Records or documents	Nominal	1
c. Simple observation	Researcher	Verbal or behavioral responses recorded by the researcher	Nominal Ordinal Interval Ratio	1
d. Hardware	Researcher	Recordings on tape, film, etc. of verbal or behavioral responses	Nominal Ordinal Interval Ratio	1

[a] The scale is meaningful only in comparing these methods; it does not reflect any absolute measurement. The scale is defined as: 1 = little or none, 2 = some, 3 = a large amount.

Table 1 (Continued)

Method	Characteristics			
	Suitability of method for exploratory research	Reactivity of the method	Source of bias	Structuring of the setting required by the method
PROCESS TRACING				
1. Verbal protocols	Yes	Reactive	Subject & researcher	Could be structured
2. Information acquisition	Yes	Reactive	Subject	Yes
APPLIED				
1. Critical incident	Yes	Could be[b] reactive	Subject	No
2. Delphi	Yes	Reactive	Subject & researcher	Yes
3. Operations research	Yes	Could be reactive	Researcher	Yes
FIELD RESEARCH				
1. Interview	Yes	Reactive	Subject & researcher	Yes
2. Questionnaire	No	Reactive	Subject	Yes
3. Observation	Yes	Reactive	Subject & researcher	Could be structured
4. Unobtrusive measures				
a. Physical traces	Yes	Nonreactive	Researcher	No
b. Archives	Yes	Nonreactive	Author (subject) & researcher	No
c. Simple observation	Yes	Nonreactive	Researcher	Could be structured
d. Hardware	Yes	Nonreactive	Researcher	Could be structured

[b]"Could be" indicates that the decision is left to the discretion of the researcher, dependent on the goals of the particular study.

2. Nature of the Data--the type of data that are collected and analyzed.

3. Measurement Scales of the Data--(a) nominal: data that are categorized on the basis of group membership; (b) ordinal: data that are ranked, but differences among the ranks are not necessarily behaviorally or numerically equivalent; (c) interval: data that are ranked on an equal-interval scale that has no absolute zero; (d) ratio: data that are ranked on an equal-interval scale that does have an absolute zero.

4. Relative Technical Expertise Required by the Method--while skill is required to perform all of the procedures effectively, in this instance technical refers to sophisticated mathematical or interpretive techniques or to complex equipment.

5. Suitability of Method for Exploratory Research--the potential applicability of the method to the study of complex or less well defined real-world behavior, and to its utility for providing rich source of data from which hypotheses can be generated.

6. Reactivity of the Method--bias or change in behavior resulting from the subject's awareness of being observed or tested.

7. Source of Bias--bias introduced in the data by either the subject or the researcher, or both, and resulting from such variables as memory limitations, selective recording of responses, or selective encoding of data.

8. Structuring of the Setting Required by the Method--whether the data can be collected from an ongoing task or account of past behavior, or whether the task environment must be structured to elicit from the subject the behaviors of research interest.

PROCESS-TRACING METHODS

Traditionally, in decision-making research the focus of investigation has been observable input-output relationships rather than the cognitive processing of information that precedes a decision. In part this has been because of the lack of an adequate methodology. Those investigators who have tested the predecisional process itself have used analyses based on algebraic models. For example, under what set of conditions is information cognitively integrated by averaging? There has been some discussion, however, about the validity of this model-fitting approach. (See Tversky, 1969, and Yntema & Torgerson, 1961, for drawbacks, and Anderson, 1981, for an alternative method for testing algebraic models.)

Process-tracing methodology offers another approach to the investigation of the cognitive analysis and evaluation of information. This methodology is derived from information-processing theory and, accordingly, is designed to identify the series of cognitive operations through which information progresses in the formulation of a decision. The series of cognitive operations is inferred from data such as the order of the information searched, what

information is examined and what is ignored, the amount of time each item is examined, and the time between information requests.

While process-tracing methodology provides detailed, sequentially ordered observations useful in developing information-processing models of individual decision behavior, it does have some drawbacks. More time and effort are required to conduct research using this method and, in particular, to analyze the resulting data. Because standard summary statistics for data collected by process-tracing studies are not well developed, the researcher may have to present the results in great detail. Nevertheless, some researchers consider process tracing a valuable adjunct to traditional input-output methods and a useful tool in exploring real-world decision making (Payne, Braunstein, & Carroll, 1978).

Two kinds of process-tracing techniques will be considered: verbal protocol analysis, and the analysis of information acquisition behavior.

REFERENCES AND SELECTED ANNOTATIONS

Anderson, N. H. (1981). Foundations of information integrating theory. New York: Academic Press.

Payne, J. W., Braunstein, M. L., & Carroll, J. S. (1978). Exploring predecisional behavior: An alternative approach to decision research. Organizational Behavior and Human Performance, 22, 17-44. (See Verbal Protocol Analysis Reference Section for an annotation of this article.)

Tversky, A. (1969). Intransitivity of preference. Psychological Review, 76, 31-48.

Yntema, D. B., & Torgerson, W. S. (1961). Man-computer cooperation in decisions requiring common sense. IRE Transactions of the Professional Group on Human Factors in Electronics, HFE-2(1), pp. 20-26.

Verbal Protocol Analysis

Definition. Verbal protocols are continuous verbal reports supplied by a subject during the performance of a task. Verbal protocols provide sequential, time-ordered information about knowledge or operations associated with particular responses.

History. The analysis of verbal protocols to obtain psychological data is not a new idea. Introspection was commonly used around the turn of the century, and for researchers such as Wundt and Titchener, it was the preferred method of psychological investigation. With the advent of behaviorism, introspection was discouraged on the basis that it was not scientific, verifiable, or repeatable. Only recently, with the availability of computers for processing complex data and the pioneering efforts of Newell and Simon (1972), has the use of verbal protocols reemerged.

It is important to distinguish between verbal protocol analysis and introspection. First, highly trained subjects, and even researchers, have been used in introspective studies, whereas subjects naive to the constructs of

research interest are used to provide protocol data. Second, subjects using introspection theorize about the causes and consequences of their behavior, in contrast to protocol analysis, where subjects are asked to report only their intention and state of knowledge at that moment. Finally, verbal protocols are collected during the performance of a task rather than retrospectively through interviews or questionnaires.

Procedure. The subject is asked to think aloud during the performance of a task. The subject should verbalize and record all thoughts, not only those judged to be of interest to the researcher. The data are the subject's verbatim responses.

Two special procedures encourage the subject to verbalize: (1) combining a verbal protocol technique with an information search procedure (defined in the next section) and (2) asking two individuals to make a joint decision (Payne et al., 1978).

Analysis. Payne et al. (1978) summarized procedures for the analysis of protocol data. Following complete transcription of the verbal report, the first step in the analysis is to break up the protocols into short phrases, each corresponding to the assessment of or reference to a single task. The next step, encoding the phrases into formal categories, is a controversial one. Newell and Simon (1972) advocate dealing with the data in the form of short phrases if possible, because encoding may result in a substantial loss of information. However, rigorous analysis of the data will probably require some form of encoding. Newell and Simon (1972) have developed one encoding method known as the problem behavior graph (PBG), which represents the sequence of operations and acquired knowledge states of a subject in the process of reaching a decision. A node, designated by a rectangle, represents a state of knowledge. A horizontal arrow to the right between two nodes represents the application of an operation to generate a new state of knowledge. Examples of operations are search, comparison, evaluation, goal statement, and choice. (See Payne et al., 1978, for a detailed example.)

Benefits and Limitations. A high temporal density of sequential data is characteristic of process-tracing techniques in general. These data are useful for making inferences about decision rules and information-processing models of decision behavior. Of particular importance is the value of this methodology to the study of real-world decision making. Although it is clear that the think-aloud procedure is not unobtrusive, the limited information about this procedure indicates that while verbal protocols slow the decision process, they do not alter it in a fundamental way (Carroll & Payne, 1977).

Another question associated with the use of verbal protocols is one of coding reliability. Empirical investigations of reliability have produced conflicting results, but Payne et al. (1978) concur with Simon and Newell (1974) that even though some subjectivity does enter into the process, it is not very great. These are two possible approaches to increased reliability. The researcher can validate interpretations of the data with other measures, such as information-search procedures or measurement of response time (such as amount of time to make a choice); and the process can be computerized (Waterman & Newell, 1973).

Applications. Verbal protocol analysis has a number of possible applications to decision research. First, it can be used for exploratory research of complex, real-world decision behavior. This methodology proves to be increasingly valuable as the decision task becomes more complex and less well defined. Furthermore, coded protocols may serve as the basis for descriptive statistics, such as the percentage of protocols falling in particular categories. Second, protocols can be used to supplement and validate data collected by other methods. Third, protocols can be used to test specific hypotheses since the data collected allow categorization and some quantification. Finally, protocols can be used to develop and test computer models of decision behavior (Payne et al., 1978).

REFERENCES AND SELECTED ANNOTATIONS

Carroll, J. S., & Payne, J. W. Judgments about crime and the criminal: A model and a method for investigating parole decisions. In B. D. Sales (Ed.). (1977). Perspectives in law and psychology: The criminal justice system (Vol. 1). New York: Plenum.

Newell, A., & Simon, H. A. (1972). Human problem solving. Englewood Cliffs, N.J.: Prentice-Hall.

Payne, J. W., Braunstein, M. L., & Carroll, J. S. (1978). Exploring predecisional behavior: An alternative approach to decision research. Organizational Behavior and Human Performance, 22, 17-44. The authors argue that in order to identify the information a decision maker uses and how it is processed, data collection methods are needed that will yield data on predecisional behavior. Two such process-tracing methods, verbal protocol analysis and the analysis of information-acquisition behavior, are illustrated and discussed. The verbal protocol method, in which a subject is asked to think aloud, is a particularly useful but relatively time-consuming procedure for exploratory research of complex, real-world decision making. Some methods for analyzing protocol data are presented. Eye movement recording and explicit information-search procedures (information boards, for example) are techniques used to illustrate information-acquisition behavior. The value of a multimethod approach, combining process-tracing techniques and input-output analysis, is illustrated and discussed.

Simon, H. A., & Newell, A. Thinking processes. In D. H. Krantz, R. C. Atkinson, R. D. Luce, & P. Suppes (Eds.). (1974). Contemporary developments in mathematical psychology (Vol. 1). San Francisco: Freeman.

Waterman, D., & Newell, A. (1973). Pas-II: An interactive task-free version of an automatic protocol analysis system. Proceedings of the International Joint Conference on Artificial Intelligence, pp. 431-445.

Analysis of Information-Acquisition Behavior

Definition. Monitoring information-acquisition behavior involves presenting a decision task in such a way that the subject's selection and examination of information can be easily monitored. This method provides data on

the information sought, the order of search, the depth of search, and the duration of examination for each piece of information.

According to Svenson (1979), three assumptions are associated with this procedure. First, a piece of information is assumed to be processed cognitively while the subject examines it. Second, directed attention is assumed to reflect the search for information necessary to comply with a predetermined decision strategy. Third, a longer fixation on a single item is assumed to represent a more complex cognitive process.

Procedure. Two general methods have been used for monitoring information-acquisition behavior. The first method, eye movement recording, has been used for a number of years in psychological research and has usually emphasized the length of time (seconds, milliseconds) the eyes are actually fixated on different types or sources of information. In decision-making research, however, the emphasis is placed on the sequence of fixations; that is, the serial order of fixation on the various sources of information. Thus, for fixation duration the data collected are the actual fixation times, whereas for fixation sequence, the data are strings of rank-ordered sources of information.

Although eye movement recordings provide data that are detailed and hard to misrepresent, some technical problems are associated with their use. The apparatus is expensive, cumbersome, and uncomfortable for the subject. In addition, only a limited amount of information can be displayed, particularly on a CRT, if eye movement is to be precisely detected. Recently, the use of videotapes has eliminated some of these problems and shows potential value as a recording device in more realistic environments (Russo, 1978).

The second method of information-acquisition analysis involves the subject's explicit search for hidden information. Three techniques have been used to collect search data. The first, information boards, consists of a matrix of envelopes attached to a cardboard sheet (Payne, 1976). The subject must pull a card out of the envelope to obtain information. Another technique utilizes a random-access slide projector (Carroll & Payne, 1977). The subject must request a specific category by number from a list; information in each category is available on one slide. A third technique, involving computer-controlled retrieval, requires that the subject press keys to display information on a CRT screen (Payne & Braunstein, 1978).

Analysis. Analysis of information-acquisition behavior is more straightforward than analysis of verbal protocols, primarily because the procedure focuses on the subject's external, objective search behavior. Thus, the data collected can be quantified and standard statistical comparisons can be easily made. In addition, more subjects are used in information search studies than in verbal protocol studies, providing the potential for revealing behavioral regularities more rapidly and reliably.

The procedure usually involves an examination of the content, amount or depth of search, and the pattern of the search. For example, one measure of particular interest in decision-making research is whether a subject searches across all the alternatives within each attribute or across all the attributes within each alternative.

Benefits and Limitations. Unlike verbal protocol analysis, information-acquisition procedures provide data only on overt behavioral responses. They do not provide information on whether or not examined items are actually being processed or information stored in memory is being used in reaching a decision. Furthermore, information-search procedures usually require the task to be more structured and less complex. Although more structure leads to more easily analyzable results, it also reduces the number and types of realistic environments in which it can be used (Payne, 1980, p. 111).

Applications. Information-acquisition procedures may be used to test specific hypotheses about the decision process. For example, a researcher can monitor the information used at a computer terminal to test hypotheses about the types of data that are used, the order in which the data are used, the influence of organizing the data base in different ways, and the point at which the search for information is completed and a decision is made. Another important use is the validation of other methods in a multimethod approach.

REFERENCES AND SELECTED ANNOTATIONS

Carroll, J. S., & Payne, J. W. Judgments about crime and the criminal: A model and a method for investigating parole decisions. In B. D. Sales (Ed.). (1977). Perspectives in law and psychology: The criminal justice system (Vol. 1). New York: Plenum.

Payne, J. W. (1976). Task complexity and contingent processing in decision-making: An information search and protocol analysis. Organizational Behavior and Human Performance, 16, 366-387.

Payne, J. W. (1980). Information processing theory: Some concepts and methods applied to decision research. In T. S. Wallsten (Ed.), Cognitive processes in choice and decision behavior. Hillsdale, N.J.: Erlbaum.

Payne, J. W., & Braunstein, M. L. (1978). Risky choice: An examination of information acquisition behavior. Memory and Cognition, 6, 554-561.

Russo, J. E. (1978). Eye fixations can save the world: A critical evaluation and a comparison between eye fixations and other information processing methodologies. In J. K. Hunt (Ed.), Advances in Consumer Research (Vol. 5). Ann Arbor, Mich.: Ann Arbor Association for Consumer Research.

Svenson, O. (1979). Process descriptions of decision making. Organizational Behavior and Human Performance, 23, 86-112. Presented in this paper is a discussion of two process-tracing techniques: verbal protocol analysis and information-acquisition procedures. A number of assumptions associated with these techniques are delineated. Studies of decision making that use process-tracing methodology are reviewed. The review indicates that an information-search pattern is a function of the number of alternatives and attributes, the presentation format of information, the use of different rules during different stages of the process, the order of decision rules, and absolute versus comparative evaluation statements about attributes. Research in each of these areas is discussed. One

important finding is that subjects make decisions without completing a search of the data. Therefore, many of the algebraic decision models which assume a completed data search are inadequate. A representation system for describing decision rules is introduced and some examples of these decision rules are given.

Cognitive Applications

The process-tracing methods have been designed specifically to investigate cognitive processes and to trace information processing. These methods are based on the rationale that to answer questions about the psychological processes involved in cognition and decision making (learning, problem solving, thinking, memory, and perception), data should be collected as frequently as possible during the subject's actual psychological processing of the task. The methods are particularly useful for studying questions like what, how, and how much information is used to make a choice or judgment; whether the information stored in memory is used; what are the effects of the presentation format of information; and what are the effects of different sources of data.

One important application of this method is the development of computer information-processing models from data generated by process-tracing studies. These models simulate the flow of information through various cognitive states and operations. Computer models afford the advantage of precision by allowing testable predictions about behavior. In addition, through analysis of the influence of particular variables on the model's components, computer models allow a determination of the locus of various effects.

There are at least three other application domains for process-tracing methods: (1) In real-world settings, process-tracing methods can be used to test and extend the results of more traditional laboratory input-output and model-fitting studies; (2) for exploratory research in real settings, these methods can be used to search for regularities in information processing and to provide the experimenter with a basis for hypothesis generation; and (3) in both laboratory and natural settings, process-tracing methods can be used to test specific hypotheses pertaining to, for example, the type of data sought by a decision maker or the influence of different data base models.

APPLIED RESEARCH METHODS

Applied research methods are typically used when the focus of an investigation is on concrete phenomena involved in practical problems. This is distinguished from a more abstract or theoretical focus common to experimental investigations.

While the applied methods described in this section are widely used, they are rarely, if ever, used to study psychological problems. The critical incident technique comes from the area of industrial and organizational psychology and is used primarily to develop criteria for evaluation and placement of personnel, as well as for job and systems analysis. Furthermore, this technique is frequently employed in human factor evaluations of design errors in systems. The Delphi method has been used as a forecasting and planning

tool for very large-scale systems and issues. Operations research is typically applied to management and control situations and recently to human factors problems of work space and display design.

This section includes separate discussions of each of these three applied research methods and concludes with suggestions for their application in cognitive and decision-making research.

Critical Incident Technique

Definition. The critical incident technique is a procedure in which incidents of outstanding behavior (both good and bad) are recorded in the form of anecdotes by qualified observers (subordinates, superiors, or coworkers). It is useful for sampling the many behaviors that make up a job or activity and for defining the actual behaviors that characterize effective of ineffective performance.

History. The technique was developed by Flanagan (1954) and was first applied to the problem of vertigo experienced by pilots in the Air Force during World War II. This study led to a number of recommendations for changes in cockpit and instrument design and in training procedures.

Procedure. Anecdotes of critical behavior are collected that describe the events leading up to the incident, the outstanding behavior performed in response to the incident, and the perceived consequences of the behavior. The anecdotes are then abstracted and grouped into unambiguous and meaningful behavioral categories. From the categorical data, a comprehensive checklist or questionnaire is derived that empirically defines critical job behaviors and can then serve as a research instrument in further job analysis. (See Campbell, Dunnette, Lawler, & Weick, 1970, for a detailed example.)

Benefits and Limitations. The critical incident technique defines an activity in terms of actual rather than ideal or desirable behavior. Anecdotes are collected from the persons best suited to provide this information--direct observers of the behavior. Further, the questionnaire is not based on a global job-success dimension. Rather, it is based on data collected from a specific group or organization and is, therefore, tailor-made for that group. To ensure sufficient coverage of the domain of required behaviors, hundreds or even thousands of incidents must be collected. This may or may not be a problem, depending on the population being sampled. The investigator should also be aware that oversimplification of behavioral dimensions will result in loss of impact and usefulness of the questionnaire.

One disadvantage of this technique is the investigator's inability to assess the relative frequency of particular behaviors. Flanagan (1954) reported that the total number of incidents recalled is a function of time and that the recall over time of certain types of incidents is selective.

Applications. The critical incident technique has been used to develop selection and classification measures, proficiency measures, and training programs, and to collect data for job and systems analysis. In addition, it is frequently used by human factors specialists to investigate accident data in order to analyze design errors in a system.

REFERENCES AND SELECTED ANNOTATIONS

Campbell, J. D., Dunnette, M. D., Lawler, E. E., II, & Weick, K. E., Jr. (1970). Managerial behaviors, performance, and effectiveness. New York: McGraw-Hill, pp. 77-83.

Chapanis, A. (1959). Research techniques in human engineering. Baltimore: Johns Hopkins University Press, pp. 88-92.

Flanagan, J. C. (1954, July). The critical incident technique. Psychological Bulletin, 51, 327-358. The development and fundamental principles of the critical incident technique are described by the author who developed the technique during the mid-1940s. A review of the results of a number of studies employing the procedure is presented. Practical applications of the technique in the areas of criteria measures, proficiency measures, selection and classification measures, operating procedures development, job and equipment design, and in the study of attitudes, motivation, leadership, decision, and choice are discussed briefly.

Delphi Method

Definition. The Delphi method is a structured communication process that allows individual assessment and revision of a group judgment while individual responses remain anonymous. As a decision-making aid, the Delphi method is used to obtain a reliable consensus from a group.

History. The Delphi technique was developed more than two decades ago by the creative effort of an Air Force-sponsored RAND Corporation "Project Delphi." It was first utilized to gain a consensus from a group of experts on the effects of a hypothetical Soviet atomic bombing attack on the United States (Dalkey & Helmer, 1963).

Procedure. Two distinct forms of the Delphi process are in use today. In the "Delphi Exercise," or conventional Delphi, questionnaires are sent to a group of participants. Following the return of the questionnaires, a monitor team consolidates the responses and develops a new questionnaire based on these results. Through repeated questioning and controlled feedback, individual estimates tend to converge. A newer form called "Delphi Conference," or the real-time Delphi, uses a computer that has been programed to summarize each round of responses.

Variations. A variation of Delphi, the "Policy Delphi," introduced by Turoff (1970), is used to generate the strongest possible opposing views on the potential resolution of a major policy issue, that is, a policy for which there are no experts, only advocates. The Policy Delphi departs from the original form of Delphi in that the decision maker is interested in being presented with all options and supporting evidence rather than with a formed consensus from the group. This technique has been of benefit as a precursor to committee activity. Participants can propose, assess, and react to differing viewpoints without fear of political or personal repercussions. The resulting viewpoints can be utilized by a small workable committee to

formulate a policy. For example, the Policy Delphi has been used to obtain a rank-ordered list of national priority areas that could create major public problems in the near future.

Another variant of Delphi, advocated by Delbecq, involves four steps. First, each participant makes an initial estimate. Second, the estimates are presented to the group. Next, participants discuss their estimates and the rationales on which they are based. Finally, each participant anonymously reaches a conclusion. The approach differs from the original Delphi technique in that direct discussion replaces the feedback provided by a monitor team.

Benefits and Limitations. The Delphi method is appropriate when accurate information is unavailable or too costly to obtain. It is also useful when a great many subjective estimates must be made in reaching a decision on a complex issue. Other advantages of this method are that participants do not have to meet in the same physical location, and that independent thought is fostered because forceful members are prevented from dominating the discussion. Delphi should not be used when the issue under discussion has been previously developed and refined; participants seldom build meaningfully on elaborated concepts.

Applications. Delphi has been used as a communication system and a technological forecasting tool. It has been widely applied to government, industrial, and organizational planning, and more recently applied to medical concerns. For instance, a Delphi was conducted to assess the impact of nutrition, family income, and prenatal care on birth weight and intellectual development. The results were incorporated into a cost-benefit analysis of government nutrition programs. In addition, the Delphi method has been used to establish priorities and isolate significant parts of a problem. For example, a Delphi was conducted with computer systems designers in order to gather and organize their knowledge about important features and characteristics of computer systems (Turoff, Hiltz, & Kerr, 1982); the points on which the systems designers disagreed highlight design choices that need empirical study. Delphi also has been applied to the study of historical events and to the evaluation of historical factors leading to the development of a technology. In general, Delphi is finding application in the more complex problem areas facing society: transportation, environment, education, and so forth (Lindstone & Turoff, 1975).

REFERENCES AND SELECTED ANNOTATIONS

Dagenais, F. (1978). The reliability and convergence of the Delphi technique. Journal of General Psychology, 98, 307-308.

Dalkey, N., & Helmer, O. (1963). An experimental application of the Delphi method to the use of experts. Management Science, 9, 458-467.

Fischer, G. W. (1975, December). An experimental study of four procedures for aggregating subjective probability assessments. (Technical Report 75-77). McLean, Va.: Decisions and Designs. Compared in this study are four opinion aggregation procedures: Delphi, Delbecq, consensus, and statistical averaging. No differences among the procedures were found in a subjective probability assessment task. The results failed

to confirm those obtained in a previous study and possible explanations for this discrepancy are discussed. Two conclusions are drawn from these results and a literature review. First, subjective probability distributions can be significantly improved by aggregating the opinions of a group of experts rather than relying on an individual expert. Second, no evidence indicates that a particular aggregation method results in an improved subjective probability distribution.

Gustafson, D. H., Shukla, R. K., Delbecq, A., & Walster, G. W. (1973). A comparative study of differences in subjective likelihood estimates made by individuals, interacting groups, Delphi groups, and nominal groups. Organizational Behavior and Human Performance, 9, 280-291.

Huber, G. P., & Delbecq, A. (1972, June). Guidelines for combining the judgments of individual members in decision conferences. Academy of Management Journal, 161-174.

Lindstone, H. A., & Turoff, M. (Eds.). (1975). The Delphi method: Techniques and applications. Reading, Mass.: Addison-Wesley. This book consists of a collection of articles that concentrate on the most recent cross-section of applications of the Delphi method. It is directed toward providing background information to professional designers and potential users. A rich source of references, nearly 700 in number, appears at the conclusion of the book.

In Chapter I, the reader is introduced to the concept of the Delphi method, its characteristics, and evolution. In Chapters II and III, a broad overview of the Delphi method is provided and its philosophical foundation, its utility, and its applications to government planning and business are discussed. In Chapter IV, systematic evaluation of the method is examined, particularly in terms of its precision and accuracy. In Chapters V and VI, some of the specialized techniques that have evolved for questioning and evaluation of responses are presented. The former deals with cross-impact analysis and the latter explores other quantitative techniques for further analysis of opinions. In Chapter VII, the modifications of Delphi brought about by utilization of computers are discussed and speculations on future applications of the methodology are presented. In Chapter VIII, a checklist of eight pitfalls is provided to which the user can refer when designing and conducting a Delphi survey.

Pill, J. (1971). The Delphi method: Substance, context, a critique and an annotated bibliography. Socio-Economic Planning Science, 5, 57-71.

Turoff, M. (1970). The design of a Policy Delphi. Technological Forecasting and Social Change, 2, No. 2.

Turoff, M., Hiltz, S. R., & Kerr, E. G. (1982). Controversies in the design of computer-mediated communications systems: A Delphi study. Proceedings of the conference on Human Factors in Computer Systems, Gaithersburg, Md., March 15-17, 1982, pp. 89-100.

Operations Research

Definition. Operations research (OR) applies specialized techniques to problems that arise in the management and control of humans, machines, material, and money in their natural environments (Chapanis, 1961). OR attempts to aid administrative decisions about system performance by providing quantitative solutions to situations involving conflicting goals. The essence of the OR approach is to construct a mathematical model of the system and conduct research in the form of simulations or mathematical analyses to derive a solution. A solution refers to the values in a model that optimize performance measures. A solution is derived by analyzing the relationships that determine the consequences of decision choices. Operations research utilizes a number of methodologies in deriving solutions. Among these methodologies are linear programing, operational gaming, inventory modeling, and decision theory.

History. Although its roots extend to the 19th-century Industrial Revolution, the term operations research was coined during World War II. OR rapidly advanced as a discipline during this period. Its present form grew out of an attempt by the British military to take action against heavy German air attack. Teams of scientists from a variety of disciplines were called in to aid the British military executives in incorporating the then new radar into military strategy. Due to the success of these teams, the United States, Canada, and France demanded similar teams of scientists that usually were assigned to the military executive in charge of operations. Following the war, defense research in Britain was reduced, thus allowing many OR specialists to be hired by industry. In the United States, however, defense research was increased and most OR specialists remained in the military service. In more recent years, with the advent of computer technology, greatly increased competition, and the need for innovative methods to collect and analyze data, operations research applications in business have grown (Ackoff & Sasieni, 1968).

Procedure. According to Ackoff and Sasieni (1968), there are five steps to the OR approach:

1. formulate the problem,
2. construct a mathematical model of the system,
3. derive a solution,
4. test the model and evaluate the solution, and
5. implement and maintain the solution in the system.

To formulate a problem, the minimum amount of information needed consists of: (1) definition of the decision maker, (2) the courses of action available and the choice preferred, and (3) determination of the controllable and uncontrollable variables and the restrictions to be placed on them.

Procedures for constructing models fall into one of five patterns, depending on the complexity of the system and the amount of access the researcher has to the system. Model construction might be based on: (1) direct observation of system operations; (2) an analogous system whose structure is better known; (3) analysis of data that describes the system operations; (4) experimental determination of relevant variables; or (5) particularly for large-scale conflicts, an artificial reality characterized as a complex game in which many hypotheses can be tested.

Numerous techniques for deriving solutions from models have been used in OR. For instance, several types of mathematical programing have been developed: linear, nonlinear, integer, dynamic, stochastic, parametric, and network analysis. They are usually applied to problems of transportation routing and allocation of resources to jobs. Another technique, queuing theory, is typically applied to problems of congestion (in traffic and telecommunications), airline passenger checkin, and passenger air terminal design. A third technique, game theory, is frequently applied to problems of competition and conflict, particularly of a military or political nature. Decision theory, still another technique, is applied to a one-person, two-person, or two-group bargaining situation in which optimum choice is made under uncertainty. An example is the one-person situation in which a judge must decide whether to release a defendant on bail (Ackoff & Sasieni, 1968; DeGreene, 1970).

Benefits and Limitations. Operations research offers a number of potential benefits: (1) better decisions because an OR model can account for more information than the human can process; (2) better coordination of decisions, for example, marketing decisions with manufacturing capabilities; and (3) better control over daily operations, to free executives from supervision of routine matters (Wagner, 1969).

While many operations research problems and techniques are of potential interest in the area of psychology, there has been little effort to create a liaison between the two fields. Topmiller (1968) reported conclusions from Leuba's review of 250 OR studies, which indicated that psychological variables were so deeply incorporated in OR models that extrication and assessment of the variables per se were very difficult. The lack of standard measures of human performance and the divergence of psychological parameters also prevent quantitative comparison. Moreover, OR tends to emphasize theory over applications and to concentrate more on the model than on the real system. A final important limitation is that operations research requires more mathematical background than most psychologists possess, or want (DeGreene, 1970).

Applications. Operations research techniques are typically applied to problems of (1) inventory, (2) allocation, (3) queuing, (4) sequencing and coordination, (5) routing and transportation, (6) replacement, (7) competition and conflict, and (8) search. Human factors problems that have been investigated with OR methods are work space design and panel layout, visual sampling and display design, information system data file and data retrieval, organizational data flow, and personnel allocation. For example, Carbonell et al. (1968) applied queuing theory to the problem of visual sampling of aircraft cockpit instrumentation. According to their model, different instruments compete, or queue, for the pilot's attention. The instruments that are looked at, or served, are those with highest priority. Priority is determined by the probability of exceeding a threshold (leading to a catastrophe) and the cost of exceeding that threshold (DeGreene, 1970).

REFERENCES AND SELECTED ANNOTATIONS

Ackoff, R., & Sasieni, M. W. (1968). Fundamentals of operations research. New York: John Wiley & Sons. The aim of this book is to provide, along with the usual mathematical treatment of the subject, a conceptual understanding of OR directed particularly toward the beginning student. In

Chapter 1, the development and nature of OR are discussed, and a general introduction to the methodology of OR is presented. In Chapters 2 through 4, problem formulation, model construction, and techniques for deriving solutions from models are discussed. In Chapters 5 through 14, specific problem types are considered in detail. In Chapters 15 and 16, methodological problems involved in evaluating the model and the solution, as well as implementing and controlling the solution in the system, are discussed. In the final chapter, the problem of long-range organizational planning is considered and the limitations and potential contributions of OR to this frontier area are discussed.

Carbonell, J. R., et al. (1968, September). A queuing model of visual sampling: Experimental validation. IEEE Transactions on Man-Machine Systems, 9, 82-87.

Chapanis, A. (1961). Men, machines, and models. American Psychologist, 16, 113-131.

DeGreene, K. B. (Ed.). (1970). Systems psychology. New York: McGraw-Hill, pp. 98-102.

Topmiller, D. A. (1968, May). Mathematical models of human performance in man-machine systems. Technical Report 68-22. Wright Patterson AFB, Ohio: Aerospace Medical Research Laboratories.

Wagner, H. M. (1969). Principles of operations research with applications to managerial decisions. Englewood Cliffs, N.J.: Prentice-Hall. This book is written at an intermediate level of difficulty.

Cognitive Applications

To date, the methods discussed in this section have not been applied in the study of cognitive and decision-making problems. However, each does show some potential for adaptation and implementation in the examination of these areas.

One possible use of the critical incident technique is to define exceptionally effective or ineffective decision processes. The incidents might serve as the basis for a cognitive job analysis. Individuals such as medical technicians or military intelligence analysts, whose jobs consist largely of cognitive activity, would be ideal populations from which to draw subjects. Two approaches might be considered in the collection of critical incidents. One is to ask subjects to speculate on how they arrived at particular faulty decisions. In other words, what factors or aspects relevant to the situation were not taken into account or were incorporated wrongly in the decision process, leading to an error? As an alternative, subjects would report correct decisions that were made contrary to those of most coworkers, and speculate about their perception and consideration of important factors or variables that preceded those decisions.

The format of and concept behind the Delphi method are well suited to its application in cognitive areas. Delphi is at its best when applied to complex areas for which many subjective estimates must be made in reaching a

decision. Using this method, a group of experts could provide estimates of the subjective process involved in a cognitive problem. Through repeated questioning and feedback, a consensus of the relevant factors and decisions could be obtained.

While there appears to be no direct way to obtain data about cognition with operations research techniques, OR models might be used for testing the implications of cognitive processing. To do this, a model representing expected or typical processing of a particular cognitive problem could be constructed. When varying amounts of information, say 20% and 50% of that required, are entered in the model, the derived solutions should predict performance and suggest the types of errors humans will make under similar conditions. In addition, the models could be used to test the consequences of already identified human biases. For example, one of the model's parameters could be the relative importance or weight given to base rate information. Solutions then could be obtained for different values of the base rate weight, such as 0%, 20%, and 80%.

FIELD RESEARCH METHODS

Field research is used to collect data from persons acting out their typical roles in natural settings rather than in the laboratory. In comparison to laboratory research, field research has a number of advantages that allow greater generality, applicability, and utility of knowledge. In the field there are both greater intensity of experience and variation of phenomena than can be stimulated in the laboratory. Moreover, laboratory conditions may not provide sufficient frequency and duration of stimulation to cross a response threshold and trigger an effect. Three contextual factors that are typically destroyed in the laboratory in an attempt to achieve controlled conditions are (1) natural time constraints such as the life span of certain phenomena, (2) natural units of behavior that occur in conjunction with particular environments, and (3) environmental complexity. Two additional factors, representativeness of treatments and setting effects, while not completely absent from the laboratory, are stronger or more dynamic in the field. Field research, however, is not without its pitfalls. Two special problems are the causal ambiguity associated with uncontrolled conditions and the greater expense of field work in terms of both time and money (Bouchard, 1976).

The major field methods of data collection are interviews, questionnaires, observation, and unobtrusive measures. Each method will be considered separately, followed by a discussion of potential applications to cognitive and decision-making research.

Interview

Definition. An interview is a conversation focused by an investigator to obtain self-report data from a respondent.

History and Applications. The interview has a long and extensive history in a wide variety of fields and has become a fixture in such areas as personnel selection, social research, clinical assessment, and anthropological field work.

Procedure. Interviews vary in terms of the amount of structure and the type of information to be obtained.

Structured interviews consist of a predetermined, standardized set of questions. The questions may be closed, in which the responses are limited to specified alternatives, or open, in which the respondent replies freely. Closed questions are more efficient in obtaining factual or easily quantifiable data, such as age or education. Open-ended questions are more appropriate when the issue is complex, when exploring the formulation of an opinion, or when the relevant dimensions of an issue are not known.

Less structured interviews are commonly used for a more intensive study of the basic issues involved in a topic, the terminology, level of understanding, or conceptualization of a topic. If the investigator is skilled at developing appropriate questions during the course of the interview, highly specific and self-revealing data are provided by the respondent. Unstructured interviews might take various forms: the nondirective interview, the clinical interview, the stress interview, and the group interview (Selltiz, Wrightsman, & Cook, 1976).

Benefits and Limitations. The interview can be used as a data collection method with nearly all segments of the population, literate or not. The investigator is afforded a good deal of flexibility in terms of collecting data about complex issues and exploring areas where questions are difficult to formulate. In addition, the interview provides a greater opportunity for the investigator to be sensitive to misunderstanding of respondents' questions. However, the freedom which the investigator is permitted can also be a disadvantage because it creates problems in comparing one interview with another. Also on the negative side, interviews place heavy reliance on the validity of verbal reports. Even if they are valid, verbal reports might be misleading, particularly regarding the causes and control of one's own behavior (Selltiz et al., 1976).

REFERENCES AND SELECTED ANNOTATIONS

Bouchard, T. J., Jr. 1976. Field research methods. In M. D. Dunnette (Ed.), Handbook of industrial and organizational psychology. Chicago: Rand McNally, pp.363-413. (See Questionnaire References section for an annotation of this chapter.)

Selltiz, C., Wrightsman, L. S., & Cook, S. W. 1976. Research methods in social relations. New York: Holt, Rinehart, and Winston, pp. 291-330. In Chapter 9, a detailed comparison of the merits and pitfalls of questionnaires and interviews is presented. Question content used to ascertain information about facts, beliefs, expectations, and intentions is discussed. Types of interviews and questionnaires ranging from rigidly standardized to unstructured are detailed. A brief section deals with the use of questionnaires in the field of sociometry, the study of social interactions. Finally, the use of visual aids during the interview is discussed.

Questionnaire

Definition. A questionnaire is a written list of questions used to obtain factual or subjective information about specified topics.

History and Applications. Like the interview, the questionnaire has been used for a number of years and in a variety of fields, especially in personnel and social psychology, consumer research, and attitude and opinion research.

Procedure. A large number of factors such as clarity, directness, and order of presentation should be considered in formulating questions and designing questionnaires. Selltiz et al. (1976) and Bouchard (1976) present a good discussion of these considerations and a number of references for further investigation.

Benefits and Limitations. Questionnaires are more economical than interviews because they can be administered to a large number of respondents simultaneously. Furthermore, little skill is needed to administer questionnaires, and more uniform measurement is possible with questionnaires as compared to interviews, because the data are limited to written responses to preset questions. In addition, the respondents may have more confidence in their anonymity and so respond more candidly. Moreover, the respondents may feel less pressure to respond immediately and so may give more carefully considered answers.

Questionnaires are limited by two main factors: (1) Only very structured questionnaires with limited responses (e.g., yes, no) can be effectively administered to the general population. Open-ended questionnaires are useful only for a relatively small, educated segment of the population. (2) If the questionnaires are mailed rather than administered, a sizable proportion of the respondents does not return them. See Erdos (1970) or Bouchard (1976) for suggestions to increase the percentage of returns.

REFERENCES AND SELECTED ANNOTATIONS

Bouchard, T. J., Jr. (1976). Field research methods. In M. D. Dunnette (Ed.), Handbook of industrial and organizational psychology. Chicago: Rand McNally, pp. 363-413. The author argues that compared to laboratory research, studies in field settings could generate very useful and applicable data. Five field research methods are described: interviews, questionnaires, participant observation, systematic observation, and unobtrusive measures. The characteristics, advantages, and disadvantages of each method are discussed in some detail.

Erdos, P. O. (1970). Professional mail surveys. New York: McGraw-Hill.

Selltiz, C., Wrightsman, L. S., & Cook, S. W. (1976). Research methods in social relations. New York: Holt, Rinehart, and Winston, pp. 291-330. (See Interview References section for an annotation of this chapter.)

Observation

Definition. Scientific observation refers to the selective focusing of attention by an investigator to obtain data in such a manner that it is possible to summarize, simplify, and systematize a behavioral event to be consistent with the investigator's research goals.

History and Applications. Observation is a pervasive activity in daily life, as well as a primary method of scientific inquiry in laboratory and field research. Observational methods are used by all the behavioral sciences, including developmental and social psychology, human factors, anthropology, and program evaluation.

Procedure. The relationship of the observer to the observed varies along two important dimensions: concealment and intervention. Concealment of the observer's role can be classified into four categories: (1) as a complete participant, the researcher conceals the investigative role and surreptitiously becomes a group member; (2) as an observer, the researcher's role is somewhat revealed but participation in group activities is carried out to minimize disruption of the situation; (3) the observer as participant is the typical anthropologist role; the researcher's role is publicly known and informants are heavily used to provide data; and (4) the complete observer is totally candid about the investigative role and may employ film, videotape, or tape recorders to gather data.

Several formalized techniques have been developed for recording on-going behavior. They are field notes, specimen records, anecdotes, and checklists.

Field notes are a running log of observations. Ideally, they should contain information about: (1) the participants (e.g., how many, who are they, and how are they related), (2) the setting, (3) the purpose of the situation, (4) the social behavior (e.g., what were its qualities, what occurred, and what were the initiating stimuli, and (5) frequency and duration of the situation. The recorded activities should be concrete and defined behaviorally; however, the researcher's inferences and personal feelings may be included, provided they are labeled as such.

Specimen records describe time-ordered behavior in its context and usually over brief time periods. This method is applied to events with specific temporal qualities, such as a music lesson or job interview. Very detailed, verbatim data are recorded, as well as the researcher's inferences and feelings. The records are usually quite lengthy; one study of a single day in one boy's life produced 420 pages. With specimen records, an attempt is made to understand the behavior of one individual in a specific setting, while field notes are used to understand behavior in a specific setting across individuals.

Anecdotes are the most widely used method for describing behavior in natural settings. Unlike the two previous methods, the behaviors of interest are selected prior to data collection and in comparison to specimen records. Anecdotes contain objective and quantifiable data.

Each of the above methods (field notes, specimen records, and anecdotes) results in a narrative record of on-going behavior. What distinguishes them

from each other in their scope--the number of individuals observed and length of the observation period--as well as the level of detail of the recorded data. Because these methods are relatively unstructured, few restrictions are placed on the type of data collected. In addition, a unit of analysis may not be well defined at the outset. Therefore, these methods are very susceptible to problems relating to validity, reliability, observer bias, and memory distortions. For these reasons, unstructured methods are more suited to hypothesis generation than hypothesis testing.

When a great deal of information about the situation of interest is known, a more structured method of collecting data is more appropriate. One such method is the checklist. It is used to record whether or not explicitly specified, operationally defined behaviors are present, and results in a frequency count of those behaviors. (Selltiz et al., 1976, provide a good description of the above methods.)

In the examination of work and equipment layout, human factors specialists might draw from a group of observational methods known as process analysis techniques. There are four types of such techniques: process charts, flow diagrams, multiple-process charts, and link analysis.

1. A process chart describes the steps in a repetitive and standardized operation such as an assembly line, through the use of symbols which denote transportation, operation, storage, and inspection. Transportation refers to the movement from one place to another of the objects or operators of interest. Operation refers to the main activity of an operator. Storage can be either temporary or controlled and refers to an object being held at one location without an operation being performed on it. Inspection can be quantitative, in which an object is counted, weighed, or measured, or it can be qualitative, in which an object is tested to determine whether or not it meets some predetermined criterion.

2. A flow diagram is a graph of a process chart showing the locations of the operations, or it may show simply the paths of movement. For example, the path of eye movements required by a pilot in the execution of a preflight check-off can be described by a flow diagram.

3. A multiple-process chart is similar to a process chart except it is concerned with multiple processes, and time values are recorded to provide information on how long each step takes. For example, a multiple-process chart could be applied to the analysis of the activities of a pilot and co-pilot in landing a plane. Videotapes or multiple observers must be used to collect data.

4. Link analysis refers to a flow diagram in which the linkages between component parts (humans and machines) are expressed statistically. Link values designate the relative importance of each link. They are obtained by counting the number of times a link is used during real or simulated operations or by having an experienced person assign the values. For example, link analysis could be applied to the eye movements of a pilot during instrument landing, in order to evaluate the layout of the instrument panel. (Chapanis, 1959)

Benefits and Limitations. Observational methods are useful when subjects cannot or will not provide self-report measures of their behavior. Observation provides descriptive data about on-going behaviors. Observation cannot provide information about perceptions, attitudes, future plans, or past or private behavior (Selltiz et al., 1976).

Serious limitations to the observational approach, especially when used in applied settings, are the following: (1) observation may affect the behavior being studied; (2) significant relationships among factors that influence behavior are difficult to determine; (3) many useless data may be collected unless behaviors of interest are clearly specified in advance; and (4) some observations are costly and time consuming (Chapanis, 1959).

REFERENCES AND SELECTED ANNOTATIONS

Altmann, J. (1973). Observational study of behavior: Sampling methods. Behavior, 49, 228-267.

Bouchard, T. J., Jr. (1976). Field research methods. In M. D. Dunnette (Ed.), Handbook of industrial and organizational psychology. Chicago: Rand McNally, pp. 363-413. (See Questionnaire References section for an annotation of this chapter.)

Chapanis, A. (1959). Research techniques in human engineering. Baltimore: Johns Hopkins University Press, pp. 71-75.

Selltiz, C., Wrightsman, L. S., & Cook, S. W. (1976). Research methods in social relations. New York: Holt, Rinehart, and Winston, pp. 251-290. In Chapter 8, the basic nature and methods of observation are discussed. A definition of scientific observation is presented and three purposes of observation are discussed. A number of applications of specific observational methods in social science fields are explicated. Two dimensions of the relationship between the observer and the observed--concealment of the act of observation and intervention in the research setting--are described. Finally, methods of observation which range from unstructured methods such as field notes, specimen records, and anecdotes, to the structured method of checklists are detailed.

Unobtrusive Measures

Definition. Unobtrusive measures are those in which the investigator plays a passive, unobserved role or avoids contact with the subject altogether by examining physical traces or records of past behavior.

History and Applications. Unobtrusive research is a very old method and is widely used by police investigators, detectives, archaeologists, and social researchers.

Procedure. Four major categories of unobtrusive measures are physical trades, archives, simple observation, and measures gathered with hardware.

1. Physical traces produced by natural erosion or accretion, such as worn tiles, missing pages, or garbage, can be indices of frequency of use. In a study of attitudes, physical traces can be used to determine, for example, whether the size of male and female grave markers reflects the amount of sexism in different communities, or in a study of decision making to determine, for example, consumer decisions regarding the disposal of various kinds of material possessions through an examination of garbage. In an additional example, the number of cigarette butts in an ashtray could be used as an indicator of the amount of anxiety generated in a meeting. Sources of misinterpretation should be carefully considered when studying physical traces because this information is a very indirect indicator of psychological processes.

2. Archives include both public and private records such as media communications; police, judicial, and institutional records; and personal communications. An example of the use of archives in a psychological study is the examination of trial transcripts or judicial records to determine whether judges are biased against members of a certain ethnic group or socio-economic status. Although archives can be useful sources of information, the investigator should be aware that records are sometimes juggled for personal or political reasons.

3. Simple observation refers to situations in which the researcher is a disguised participant or is completely concealed. Any treatment is applied and data are collected without the subjects' knowledge. Simple observations can provide information on nonverbal phenomena like social distance, dominance, order of participation, amount of interaction, and choice among alternatives.

4. Hardware such as tape and video recorders, still and infrared photography, telemetry, and voice transmitters provide an enormous potential for data collection. (Webb, Campbell, Schwartz, and Sechrest, 1966, and Sechrest, 1979, provide discussions of the above methods.)

Benefits and Limitations. Unobtrusive measures are appropriate when overt, situational behavior or traces of past behavior can satisfy some research interest. The primary advantage of unobtrusive research is that the behavior under study is not contaminated by reactivity, i.e., the subject is unaware that she or he is being observed or tested. Lack of reactivity does not guarantee, however, that the results are valid, as there are other possible confounding sources such as selective recording of archives or deliberate original distortion of traces.

Practical and ethical factors should be considered when conducting unobtrusive research. Invasion of privacy may be an issue when observing a subject or examining personal records. In addition, certain records, especially private records and sometimes police or judicial records, are difficult to obtain.

REFERENCES AND SELECTED ANNOTATIONS

Bouchard, T. J., Jr. (1976). Field research methods. In M. D. Dunnette (Ed.), Handbook of industrial and organizational psychology. Chicago: Rand McNally, pp. 363-413. (See Questionnaire References section for an annotation of this chapter.)

Sechrest, L. (Ed.). (1979). Unobtrusive measurement today. Washington, D.C.: Jossey-Bass.

Webb, E. G., Campbell, D. T., Schwartz, R. D., & Sechrest, L. (1966). Unobtrusive measures: Nonreactive research in the social sciences. Chicago: Rand McNally. The book presents an extensive survey of unobtrusive methodologies employed to obtain social science data. The authors criticize the wide use of the interview and the questionnaire in social science research on the basis that they create as well as measure attitudes, they elicit atypical roles, and they are limited to cooperative populations. The authors seek to present alternative and frequently imaginative approaches that avoid these biases. The approaches can be used in conjunction with other methods to cross-validate results.

In Chapter 1, the issue of multiple operationism is addressed. This refers to confirmation through multiple methods, each having different bias patterns. In Chapter 2, the study of physical traces created by natural erosion or accretion is considered as a method to investigate past behavior. In Chapters 3 and 4, the use of archives, records produced for purposes other than those which are scholarly are examined. The former focuses on continuous archives such as actuarial records; political, judicial, and governmental records; and media communications. In the latter, discontinuous, private records such as sales records, industrial and institutional records, and personal documents are examined. The final two chapters discuss observation of behavior. In Chapter 5, situations in which the observer plays a passive, unobserved role are discussed. In Chapter 6, studies in which the observer is concealed but structures the situation by the use of hardware or a confederate are detailed. An extensive collection of references concludes the book.

Cognitive Applications

Field methods have generally been used in the study of behavioral and task-related variables. However, observation, interviews, and questionnaires can also be used to explore cognition and decision making with only a shift in the focus from overt to covert variables. Interviews, with question design based on observed performance and laboratory research, could be conducted to explicate the subjective process leading to a decision or judgment (e.g., medical diagnosis). For further investigation, questionnaires could be derived from interview data and administered on a larger scale. The results would provide insight into information processing, perceptual, and decision-making issues. As with the traditional use of these methods, however, the results would be colored by subject bias and recall limitations.

Unobtrusive observation can be used to study actual decision-making behavior in the real world. For example, Ebbesen and Konecni (1978) investigated judges' bail-setting decisions experimentally (in simulations, and unobtrusively) in real court hearings. Ebbesen, Parker, and Konecni (1977) examined drivers' intersection-crossing decisions in laboratory simulations and at real intersections. In both of these studies, unobtrusive observation proved not only useful, but crucial, to the proper interpretation and validation of laboratory findings.

The increasingly widespread use of computers in business settings should enable researchers to validly and unobtrusively measure cognitive processes. For example, questions pertaining to cognitive biases could be disguised and incorporated in computer software. The operator would answer them while proceeding through a sequence of job-related computer procedures. Similarly, questions could be asked of students using computer-aided instruction. Compared with a job-related sequence of questions, questions incorporated in computer-aided instruction software would probably run little risk of arousing the operator's suspicion since the procedure is less apt to be routine. Therefore, embedding and concealing questions should be more easily accomplished.

REFERENCES

Ebbesen, E. B., & Konecni, V. J. (1975). Decision making and information integration in the courts: The setting of bail. Journal of Personality and Social Psychology, 32, 805-821.

Ebbesen, E. B., Parker, S., & Konecni, V. J. (1977). Laboratory and field analyses of decisions involving risk. Journal of Experimental Psychology: Human Perception and Performance, 3, 576-589.

CONCLUSIONS

1. Nonlaboratory methods for the study of cognition and decision processes do exist. Methods found to be useful are (1) verbal protocol analysis, (2) information-acquisition behavior, (3) critical incident technique, (4) Delphi method, (5) interviews, (6) questionnaires, (7) observation, and (8) unobtrusive measures.

No procedure will ever allow direct assessment of covert cognitive processes. Inferences from behavior will always be required. Of the eight methods, the first two (categorized as process-tracing methods) were designed specifically for the study of cognition. They require little adaptation to be used in nonlaboratory settings and can provide much specific information about memory, problem solving, decision making, and perception.

The next four methods (critical incident, Delphi, interview, and questionnaire) rely heavily on retrospection and self-report. Because of the likelihood of inherent biases such as recall limitations, these methods can be better used for collecting data to generate rather than test hypotheses.

Observation of behavior and unobtrusive measurement of artifacts, archives, and on-going behavior in natural settings are also valid methods to assess cognition. However, because of the possible need for a larger number of assumptions to infer cognitive processing, and the potential for collecting voluminous amounts of data, these two methods also might be better for hypothesis generation.

Operations research, the ninth method explored in this report, does not provide a way to assess cognitive processing. It could be useful, however, for developing models, and for testing and predicting the implications of such processing.

2. Most nonlaboratory methods will require creative adaptation before they can be employed in research. A prerequisite for any effort toward adaptation is a determination of which cognitive processes (e.g., perception, learning) are required in the performance of a particular task. Therefore, both a background knowledge in human cognition as well as a thorough understanding of the task are necessary.

3. The computer environment will provide a rich and flexible context for applying nonlaboratory techniques and methods. Examples are: (1) protocols and information-acquisition strategies can be unobtrusively collected by examining the interactive dialogue between the computer and user; and (2) data collection (questionnaire, interview information, information usage) can be easily, continuously, and perhaps surreptitiously accomplished by monitoring user activity with the computer.